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**The Functional Form of Price-Wage  
Equations in Canadian  
Macroeconometric Models**

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## THE FUNCTIONAL FORM OF PRICE-WAGE EQUATIONS IN CANADIAN MACROECONOMETRIC MODELS

### 1 Introduction

This paper outlines the short-run price/output adjustment process and the theory of price determination as it is understood to be implemented in the price-wage sectors (defined to include the exchange rate) of eight Canadian macroeconomic models. Although a complete explanation of the adjustment process and the initiation and propagation of inflation can be found only within a fully integrated macro model, the discussion of the determinants underlying the price-setting process is limited here to those explicit within the price and factor-cost equations. This approach necessarily implies that certain variables are assumed exogenous that are not exogenous in a complete macro model. Moreover, the price-wage sector may appear to be the only place where nominal magnitudes can be determined because of this focus. In fact, some or all of the equations in this sector can be solely mechanisms for generating a particular adjustment process or definitions that ensure, for example, that income distribution in the model corresponds to the production technology.

The view that Canadian macro modellers have about the adjustment process and inflation is obtained in each case through examination of the specification of the model equations in the price-wage sectors. The models surveyed include RDXF and SAM (Bank of Canada), QFS (the Finance Department), CANDIDE (the Economic Council of Canada), FOCUS (the Institute for Policy Analysis at the University of Toronto), TIM (Informetrica Limited), MACE (the University of British Columbia), and the model developed by Data Resources (of Toronto) Incorporated. The econometric literature of price determination contains a wide variety of alternative specifications for both price and wage equations. The approaches taken by Canadian model builders in specifying their functional form has been similarly varied. Two factors affecting the choice of specification are the level of disaggregation of the individual models and the relevant time period. Those models reviewed here vary in level of disaggregation from the relatively small (e.g., SAM) to the relatively large (e.g., CANDIDE), and are evenly divided between quarterly models (RDXF, QFS, FOCUS, and the DRI model) and annual models (CANDIDE, TIM, MACE, and SAM).

Section 2 presents a reasonably standard view of the form of price and wage equations and some discussion of their implications for price

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dynamics. The markup price equation and Phillips curve wage equation used here have much in common with those found in larger econometric models and serve as a basis for comparison. In Section 3 there is some discussion of the elements required for the absence of long-run price determinancy or "accelerationist" type results, along with production function constraints and short-run adjustment and international influences. Sections 4 and 5 review the eight Canadian models, first examining the four quarterly models and subsequently the four annual models. A sixth section examines the price response of the full models to three simulated shocks, drawing upon the discussion of the specification of the individual price-wage sectors. A final section summarizes the above.

## 2 A Standard View of the Price-Wage System

### 2.1 The Price Equation

The empirical literature has generally concentrated on some variant of the markup-pricing model. In each of these models changes in unit variable costs are prominent, such that a simplified version may be written as

$$P = mUVC \quad (1)$$

where  $P$  is the price level,  $UVC$  is unit variable cost, and  $m$  the ratio of price to cost (i.e., the markup, usually assumed to be  $\geq 1$ ).<sup>1</sup> Where  $m$  is assumed to be constant, price is simply a function of costs. More commonly, changes in demand are felt to affect the profit-maximizing price and hence the optimal markup over unit costs (or, more intuitively, the greater the demand for goods the higher producers will be able to raise their price relative to cost). Thus the markup is described as a function of excess demand in the goods market ( $D_{EG}$ ), with this type of price-setting behaviour rationalized on the basis of firms operating under monopolistic or quasi-monopolistic conditions (recall that in disequilibrium all firms must be quasi-monopolistic). The combination of these factors in an equation in estimable form produces, written log-linearly,

$$\ln P = a_0 + a_1 \ln UVC + a_2 \ln D_{EG} \quad (2)$$

with the excess-demand term appropriately normalized. If  $a_1$  is 1 (a condition often not met empirically), so that there is full pass-through of cost increases to prices, and when there is no excess demand, prices

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1. A particular version, target-return pricing (originated by O. Eckstein) in which the firm sets a target rate of return on its capital stock, has received considerable attention. For a short derivation of this model see Wilder, et al. (1977).

are determined entirely by variations in unit costs on a one-for-one basis. A wide variety of variables have been used to measure excess demand in the products market, among them capacity utilization rates, inventory-to-sales ratios and unfilled orders-to-shipments ratios.

## 2.2 The Wage Equation

Labour costs have long dominated empirical investigations into cost factors affecting final price, often being introduced as the only cost in the price equation.<sup>2</sup> This has led to the close association between the wage and price sectors in macro models. Wages respond positively to the tightness of labour markets as originally envisioned in the Phillips curve. It is generally accepted, however, that workers bargain, to at least some extent, in terms of real wages rather than nominal wages when dealing with future contracts. Incorporation of expected price movements in the wage equation yields what is often referred to as the augmented Phillips curve, written here in log-linear form,

$$\Delta \ln W = b_0 + b_1 (\Delta \ln P)_t^e + b_2 \ln D_{EL} \quad (3)$$

where  $W$  equals the wage level,  $(\Delta \ln P)_t^e$ , is expected price inflation over the relevant time interval at period  $t$ , and  $D_{EL}$  is the degree of excess demand, appropriately normalized, in the labour market (as, for example, represented by the unemployment rate). The unobservable price inflation expectation variable is typically generated by a distributed lag on past values of the variable, such that

$$(\Delta \ln P)_t^e = \sum_{i=0}^n c_i \Delta \ln P_{t-i} \quad \text{where} \quad \sum_{i=0}^n c_i = 1. \quad (4)$$

In the complete absence of money illusion the coefficient on expected inflation in the wage equation ( $b_1$ ), equals 1, and wage earners bargain for real wages only (often referred to as the Phelps-Friedman hypothesis).<sup>3</sup> Several points can be made about the price-wage process as described by equations (2) and (3). Note that it is possible for the

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2. Note that wages will often be referred to interchangeably with factor costs, given the traditional importance of the former among the latter.

3. It should be noted that numerous authors have referred to the inability of this type of wage equation to capture adequately the institutional features of the labour market. Christofides, et al., for example, point out that a correctly specified wage equation "requires a very complicated set of time-varying distributed lag weights to reflect varying contract lengths, deferred increments, front-end loading and a non-uniform bargaining calendar" (1980, p. 167). Given the constraints of aggregate time-series data, however, none of the models reviewed here deal with this problem in a significant manner.

level of excess demand to affect price not only directly through the markup, but indirectly through its influence on costs. More importantly, the system as it appears has the potential to be highly autoregressive, with considerable inertia in wage inflation. This latter point raises the issue of price determinacy within the price-wage system.

### 3 Some Observations on Price Determinacy, Production-Function Constraints and the Short-run Adjustment Process, and International Influences

#### 3.1 Price Determinacy

Assume that unit variable costs are represented entirely by unit labour costs (ULC), such that unit costs are essentially determined by the wage rate, and that cost increases are passed entirely through to prices ( $\Delta \ln UVC = \Delta \ln ULC = \Delta \ln W$  and  $a_1=1$ ). Also assume for the moment that price expectations are such that price increases feed into costs instantaneously and completely ( $P_t^e = P_t$  and  $b_1=1$ ). In this case the price and wage equations are linearly homogeneous in their arguments such that full neutrality exists. Rewriting equations (2) and (3) under the assumptions above, we have

$$\ln (P/W) = a_0 + a_2 \ln D_{EG} \quad (2')$$

$$\text{and } \Delta \ln (W/P) = b_0 + b_2 \ln D_{EL} \quad (3')$$

The system merely equates the offered real wage from (2') with the demanded real wage from (3'). The money-price level and the nominal wage rate are then indeterminate unless another equation explaining either one of them as a function of an exogenous numéraire is introduced into the system.

Temporary non-homogeneity can arise via lags in the adjustment process. If inflation expectations are formed, for example, by the process described in equation (4) then a short-run trade-off will exist between inflation and unemployment. This too is ultimately indeterminate, however, as the cumulative impact is the same as in the first case. It is this indeterminacy combined with the presence of a short-run trade-off that turns the inflationary process into an accelerationist wage-price spiral. Given complete pass-through of costs to price ( $a_1 = 1$ ) and ultimately prices to costs ( $b_1 = 1$  in the long run), then the long-run Phillips curve is vertical. A sustained attempt to maintain  $D_{EL}$  above (i.e., unemployment below) the equilibrium level dictated by the long-run Phillips curve will cause the rate of inflation to continually increase over time. The continual acceleration of price increases in the absence of a stable value for the rate of inflation is often referred to as the "acceleration hypothesis". Of course, if  $b_1 < 1$  then wage earners do not bargain entirely in terms of real wages, allowing for the possibility of a

long-run trade-off (also if  $a_1 < 1$ ). This would make the price level determinate within the system formed by the price-wage equations. Thus, the method by which expectations are formed, and the estimated values of  $a_1$  and  $b_1$ , are crucial to the dynamic response of the system.

Lags need not appear only in the expectations variable. A number of factors may contribute to impede the adjustment process (for example, the existence of uncertainty). This has often been dealt with in estimation through the introduction of a lagged dependent variable in the equation, although this constrains the lag effect to be the same for all variables (including the demand variable) and to have geometric weights. An alternative is separate distributed lag models for individual variables. Note that nonhomogeneity may be introduced due to institutional factors. This may take the form, for example, of government intervention in the pricing process (for example, the historical Canadian experience with energy-pricing policy, and wage and price controls).

There has as yet been no discussion of the role of the money supply in determining prices. Although the price equation can be approached as a function of costs, as will be shown in the next section, these costs are ultimately dependent on the money supply in most standard macro models (regardless of the exact mechanism of transmission). It is generally agreed that a sustained inflation could not occur without facilitating increases in the money supply. From this view the aggregate price and wage equations described constitute the dynamic short-run path of the inflationary process. In a model with disaggregated prices it is essentially relative prices that are being determined in the long run. Thus, it is important to stress that the examination of the price-wage (factor cost) sectors here must be regarded as incomplete when dealing with the long-run determinants of inflation. In particular, excess demand in both the labour and goods markets has been treated as effectively exogenous, although price and wage movements have an obvious role in explaining unemployment and demand. It must be kept in mind that the full inflationary process can be viewed only in a complete macro model with, for example, labour market, financial and final demand sectors.

### 3.2 Production-Function Constraints and Short-run Adjustment

Nordhaus (1972) criticized the markup approach to price determination on the grounds that the specification was inconsistent with profit maximization starting from a production function. Under the neoclassical theory of price behaviour in which a firm maximizes the expected value of discounted profits, an optimal long-run equilibrium pricing rule may be derived directly from the firm's technology. In fact it is just the firm's cost function, normalized by output, since the long-run perfectly competitive equilibrium price is the minimum of the long-run average cost curve. Thus, for example, if the representative firm faces a Cobb-Douglas technology (with capital and labour as factor inputs) and

perfect markets, then long-run equilibrium prices evolve according to

$$\ln P = a_0 + a_1 \ln ULC + a_2 \ln UKC \quad (5)$$

where  $a_1 + a_2 = K$ , and  $K$  is the degree of homogeneity, which is one for constant returns to scale. It is important to note here that taking account of the firm's optimization problem has introduced the price of capital to the price function. More generally, the prices of all factors of production, and not just that of labour must be included in the price equation. Secondly, since (5) is actually a unit cost function, it is itself a dual representation of the technology, and thus must satisfy all properties assumed for the underlying technology (homogeneity, curvature, etc.). Finally, (5) can be easily specified given information on the respective shares of labour and capital in the sector or economy to be modelled.<sup>4</sup>

The difficulty with the specification in (5) is that we do not observe firms or the economy in a sequence of long-run competitive equilibria. The existence of adjustment costs associated with changes in the levels of stocks presents firms (and the macro modeller) with a dynamic problem in which the optimal approach path to the desired steady-state stock (or steady-state growth path) must be chosen. An explicit solution to such a problem can be quite complicated even with relatively simple technologies, and will depend greatly on the way in which adjustment costs are introduced into the production and cost functions. One very naïve but simple way in which a disequilibrium element can be introduced into a price equation is to add an excess-demand-for-goods term to (5), i.e.

$$\ln P = b_0 + b_1 \ln ULC + b_2 \ln UKC + b_3 \ln D_{EG} \quad (6)$$

Higher demand for goods requires a higher desired stock of capital, and if this cannot be adjusted costlessly, the demand will be met by a combination of greater use of labour, price increases, and more capital used at the expense of some costs. In the long-run steady state, without excess demand and with all stocks at their desired levels,  $b_1$  and  $b_2$  must continue to represent the equilibrium shares of labour and capital. This creates a problem out of equilibrium, however, since both labour and capital are assumed to be affecting price as they would if being combined

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4. Nordhaus and others have pointed out that the duality hypothesis between the production function and cost (i.e., price) function has often been ignored in the construction of large-scale macroeconomic models, such that even in the long run an increase in factor costs does not produce an appropriate increase in price. Note that the presence of specific factor costs in the production function need not necessarily imply that they appear directly in the individual price equations. Rather, their impact may be felt through indirect channels which have the same effect in the long run.

in an optimal way. The fact that they are not implies that constraining these coefficients to their share values will introduce a bias to the estimation of the other parameters. If  $b_1$  and  $b_2$  were estimated freely, the equation would not likely display directly the required equilibrium properties.

However, after Nordhaus's analysis and his conclusion that the presence of capital costs (and other factor costs if they appear in the production function) should, at a minimum, be econometrically tested for in the equations, many researchers have adopted specifications similar to equation (6). The inclusion of factor prices other than that for labour implies, of course, that appropriate equations must be specified for them. For accelerationist results to be maintained inflation neutrality is now required not only in the labour market, but in all other factor markets as well.<sup>5</sup>

To simplify further discussion, homogeneity of degree one and UKC and ULC appropriately defined so that  $b_1 + b_2 = 1$  are assumed, although neither  $b_1$  nor  $b_2$  necessarily equal their shares because of the reason cited above.

### 3.3 International Influences

In addition to domestic costs, import costs are an important factor in determining the price of final demand deflators in an open economy. They are often included not only on the basis of the direct purchase of foreign goods and services to satisfy final demand, but also on the basis of the perceived impact of import-competing goods on the domestic price-setting process. To demonstrate their role in the former context we take the small open economy assumption of import prices being set in world markets (converted to Canadian dollars via the exchange rate), and use  $s$  to represent the proportion of final demand composed of imports; then

$$\ln P = (1-s) \ln P_D + s \ln P_F \cdot PFX \quad (7)$$

from (6)  $\ln P = (1-s)a_0 + (1-s)a_1 \ln ULC + (1-s)a_2 \ln UKC$

$$+ s \ln P_F \cdot PFX + (1-s)a_3 \ln D_{EG} \quad (8)$$

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5. Note that if the price function were formally derived as the dual to a CRS production function, pass-through of costs to prices would be equal to unity. If inflation neutrality exists in the factor markets (i.e., there is complete pass-through of price to costs) the price level becomes indeterminate. To "pin down" the price level under these circumstances it would be necessary to exogenize one or more component prices and/or costs.

$$\ln P = a_{10} + (a_{11} \ln ULC + a_{12} \ln UKC + a_{13} \ln P_F \cdot PFX) + a_{14} \ln D_{EG} \quad (9)$$

$$a_{11} + a_{12} + a_{13} = 1$$

where  $P$  is the final demand deflator,  $P_D$  is domestic price,  $P_F$  is the relevant foreign price and  $PFX$  the exchange rate expressed in terms of units of the domestic currency per unit of the foreign currency. Note that while the coefficients for labour and capital costs have been altered, the price equation remains homogeneous of degree one with respect to costs.

However, import prices need not necessarily represent a cost variable. As mentioned above domestic producers may take import prices into account where foreign competition is a factor, and set their prices accordingly (sometimes referred to as "entry-limit pricing" under the assumption that producers will set prices below the market entry price of importers). This interpretation of the effect of import prices may appear, for example, if equation (9) were to represent the domestic value-added deflator (ignoring for simplicity the role of imports as intermediate inputs). A non-zero value for  $a_{13}$  implies that producers are (partly) price takers, taking into account their negatively sloped demand curves in their pricing decisions. This indicates some degree of monopolistic competition (also assuming  $a_{13}$  does not equal 1), while a value of zero for  $a_{13}$  would suggest that domestic producers are price setters.

The inclusion of exogenous foreign prices need not prevent homogeneity from existing within the price-wage (factor cost) system, depending on the specification of the exchange rate. Under a fixed exchange rate regime, the introduction of import prices in the context of equation (8) will provide a long-run anchor to price determination (as the pass-through of costs to prices is less than unity) in the sense that accelerationist results are not obtained.<sup>6</sup> Under a flexible exchange rate, however, the endogeneity of  $PFX$  may reestablish the wage-price spiral in the form of the so-called wage-price-exchange rate vicious circle. Assume, for example, that purchasing power parity between foreign and domestic prices enters as a determinant in the exchange rate, such that

$$\ln PFX = d_0 + d_1 \ln P/P_F + d_2 \ln f(v) \quad (10)$$

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6. The ability of a fixed exchange rate to "control" inflation is due only to the fact that we are dealing with a partial (price-wage) model in which foreign prices are held constant and the effects of external flows are ignored.

where  $v$  is a vector of other variables affecting PFX. If purchasing power parity holds completely, i.e.,  $d_1 = 1$ , then an increase in domestic prices will bring about a proportionate increase in import prices through a depreciation in the exchange rate. In this case a one per cent increase in unit labour and capital costs will raise the price level by one per cent (given the logarithmic form of the equation). It is possible therefore for the price-wage system, now defined to include the exchange rate, to remain accelerationist.

I now turn to a discussion of the price-wage sectors in each model, examining in detail the functional specification of the equations. Of particular interest are the determinants underlying the short-run inflationary process, and the degree to which the requirements for long-run price indeterminacy (resulting in accelerationist behaviour when there is a permanent increase in excess demand) are met within the price-wage sectors (defined to include the exchange rate).

#### 4 Four Quarterly Models

##### 4.1 RDXF (Bank of Canada)

RDXF is a medium-size econometric model of approximately 400 equations, designed to be easy to utilize for both forecasting and policy analysis. One method for modelling the price deflators in a fairly disaggregated model is to specify them as being relative to an aggregate price index (for an example, see FOCUS). An alternative approach, employed by RDXF, is to specify the prices individually and then to combine them into aggregate series. While this latter method facilitates estimation in an appropriate manner, it has the possible drawback that the individual equations may not be defined in a mutually consistent manner. Thus the domestic price equations that appear in RDXF, while generally based on the markup approach described earlier, are not necessarily the result of a single unified theory. Consumer prices are based on nine separate consumer expenditure deflators that are subsequently combined by near identities into the CPI using fixed-expenditure weights that sum to unity. The general form of the equation, in log-linear form, is

$$\begin{aligned} \ln(P/(1+TX)) = & a_0 + a_1 \ln ULC_n + a_2 \ln UKC_n + a_3 \ln P_T \\ & + a_4 \ln P_{EN} + a_5 \ln P_{OTH} + a_6 CAPU \\ & + a_7 \ln(P/(1+TX))_{-1} \end{aligned} \quad (11)$$

where  $TX$  represents indirect sales tax rates,  $P_T$  trade prices (both import and export),  $P_{EN}$  energy prices,  $P_{OTH}$  other prices, and  $CAPU$  is a measure of capacity utilization.

In addition to the unit prices of labour and capital, the prices of energy, traded goods and other factors are included as costs. Labour costs are easily the most important cost faced by a firm, appearing in all consumer price equations. They are usually specified as normalized ULCs, but also appear as the wage level divided by trend factor productivity, or as in the case of the services deflator simply as the wage level. Unit costs are normalized in RDXF by using output at trend factor productivity (exogenously defined) in the denominator, thus avoiding price responses to variations in short-run productivity. Capital costs, also normalized, appear in only two of the deflators (household durables and other durables), implying a very weak direct effect on price. To reflect the import content of domestic sales most deflators include some form of a trade price. This is ordinarily a closely associated import price, although in one case an export price is used (which in turn is heavily influenced by an import price). The price of energy is specified as a consumer price rather than an expenditure deflator, and is composed of four endogenous components: fuel oil, gasoline, natural gas and electricity. Each component equation, however, includes a substantial proportion of determinants that are set exogenously, reflecting the strong policy influence in these variables. In turn, the price of energy enters as an intermediate cost in each of the domestic deflators, with the coefficients ( $a_{4s}$ ) imposed on the basis of the 1976 input-output data. Other prices include the price of agricultural products in the deflator for food.

In estimation no aggregate constraint has been placed on the cost coefficients. Partial-model test simulations (with the September 1983 version of RDXF) reveal, however, that the CPI is nearly homogeneous with respect to factor costs. A one per cent increase in all cost variables will, in the long run, raise the CPI by 0.97%. Under normal circumstances part of this homogeneity property is lost due to the exogeneity of some of the components, particularly energy. The influence of excess demand in the goods market is captured by a capacity utilization term; the ratio of real gross private business output to trend output. The CAPU variable enters in level terms, allowing for a mild non-linearity, and with either eight- or ten-quarter moving averages to reflect the slow response of price to demand pressures. Only two of the consumption deflators in RDXF (motor vehicles and services excluding rent) employ this variable, however, indicating that excess demand will have its primary influence through the wage equation.<sup>7</sup> With respect to the treatment of taxes, all prices except food and rent are estimated net of indirect sales taxes on

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7. It should be noted that ULCs contain an element of demand not derived strictly from the wage equation. Unit costs, as mentioned above, are normalized by dividing them by supply output (output at trend productivity). A 1 per cent increase in employment will raise labour costs by an equivalent amount (abstracting from the effect of wages), but supply output will rise by only labour's share in the production function (approximately 0.7 per cent), allowing for a net increase in ULCs.

the assumption that they are passed fully and immediately through to price. Finally, the adjustment mechanism takes the form of lagged dependent variables in most equations.

The deflators for both business and residential investment are specified similarly to the consumption deflators, and follow the form

$$\begin{aligned} \ln(P/(1+TX)) = & a_0 + a_1 \ln W + a_2 \ln P_T + a_3 \ln P_{EN} \\ & + a_4 \text{CAPU} + a_5 \ln(P/(1+TX))_{-1} \end{aligned} \quad (12)$$

Labour costs are relatively more important than in the consumption deflators while capital costs do not appear at all. The CAPU term enters in both business-investment equations giving excess demand a significant role to play in this sector. Trade prices are also prominent in these deflators, reflecting the large import content of investment goods. The residential-investment equation incorporates the export price of lumber, used to describe the influence of the U.S. housing market on this category. Both business-investment deflators, although not that for residential investment, are homogeneous of degree one with respect to costs.

The small direct impact of capital costs and aggregate demand on price means that RDXF tends to reflect the strong historical emphasis placed on labour costs, with secondary roles played by import prices and energy costs. The crucial wage measure employed by the model is that for the private sector, specified on the basis of an expectations-augmented Phillips curve. Estimated in first-difference form the equation is

$$\begin{aligned} \Delta \ln W = & b_1 \Delta \ln TFP + b_2 (RU - RNU) + b_3 \Delta \ln P_{CPI}^e \\ & + b_4 \Delta \ln (P_{GPP}/P_{CPI}) + b_5 \text{AIB} \quad b_3 = 1 \end{aligned} \quad (13)$$

where TFP is trend factor productivity, RU the rate of unemployment, RNU a measure of the "natural" rate of unemployment,  $P_{CPI}^e$  the expected level of the CPI,  $P_{GPP}$  the price level for gross private business product, and AIB a dummy variable to represent the impact of the Anti-Inflation Board. The measure of trend factor productivity is derived from the model's Cobb-Douglas production function. It enters with a 12-quarter moving average as changes in trend productivity growth are only slowly incorporated in wage bargaining. Excess demand is represented by the labour gap: the difference between the observed unemployment rate for the entire economy and the rate of unemployment at trend output (an endogenous variable). The price-inflation-expectations term is an eight-quarter polynomial distributed lag on the four-quarter growth rate of the CPI.

The sum of the coefficients is constrained to one (a result not rejected by the data), reflecting the absence of long-run money illusion (and therefore an accelerationist view of the price determination process). A somewhat unusual variable is the relative price term,  $P_{GPP}/P_{CPI}$ , which represents the ratio of producer prices to consumer prices. It is included on the hypothesis that the higher the ratio the greater is the firm's ability to afford wage increases (similar to the profit variables sometimes found in the literature). This somewhat offsets the effect of the expectations term, as a higher value of  $P_{CPI}$  will initially reduce the firm's ability to pay. Finally, as is typical of Canadian wage equations, a dummy variable for the Anti-Inflation Board is included. This measures the downward pressure exerted on wages by the AIB from October 1975 to December 1978.

The inclusion of capital costs implies that the "price" of capital will have a bearing on the dynamics, and neutrality, of the system. The cost of capital in RDXF is represented by two imputed rental prices of capital (for non-residential construction, and machinery and equipment). They are constructed on the basis of Jorgensonian rates of return equal to the discounted present value of the price of capital goods net of depreciation and taxes.<sup>8</sup> To proxy the expected market price of investment goods the current period values of the appropriate investment deflators are used (implying static expectations in the normalized UKC terms). As these deflators respond with unit elasticity to costs, an absence of long-run money illusion in the capital cost terms is indicated. The discount rate is an approximation to the real supply price of capital in RDXF, based on the cost of equity capital, and in turn is linked behaviourally to long-term bond rates.

Import prices are usually specified as a function of foreign (U.S.) prices converted to Canadian dollars by the exchange rate. The foreign prices are either specified directly as a closely related U.S. price deflator, or as a function of U.S. costs (labour costs, crude oil prices) plus a U.S. CAPU term to represent demand pressure. Export prices are modelled in a similar manner, employing both foreign prices and the exchange rate. Most trade prices relevant to the domestic deflators respond quickly with near unit elasticity to a one per cent depreciation of the Canadian dollar. Several, however, react slowly with a long-run

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8. The general form of the equations is

$$c = q(r+s)(1-zu)(1-k)/(1-u)$$

where  $q$  = the market price of investment goods

$r$  = the discount rate

$s$  = the rate of depreciation (a constant)

$z$  = the present value of depreciation allowances

$u$  = the corporate income tax rate

$k$  = the federal investment tax credit rate times the share of eligible investment.

This type of functional form for the cost of capital is common to most econometric models.

response that is ultimately below unity (the import price of other consumer goods and the export price of motor vehicles). In the case of the import price of other consumer goods this does not necessarily preclude accelerationist results, as the sum of the elasticities with respect to its determinants (which include domestic unit labour costs) is about unity. The exchange rate in RDXF includes, among other factors, a purchasing-power-parity term ( $P/P_{us}$ ) with a long-run coefficient of unity.

RDXF thus contains a number of features that would be expected in an accelerationist model. The aggregate CPI equation is nearly homogenous with respect to factor costs. In addition there is an absence of money illusion in the wage and capital cost equations, and a purchasing-power-parity-term with unit elasticity in the exchange rate. Accelerationist results are not obtained, however, primarily because some costs are exogenous (e.g., a substantial portion of energy).

#### 4.2 QFS (Department of Finance)

The QFS (Quarterly Forecasting and Simulation) model is similar in structure to the RDX series of models developed at the Bank of Canada, and is of approximately equal size. Rather than model the GNE implicit price deflators, however, QFS uses the CPI components to model the disaggregated consumption prices. Consumer deflators in turn respond equiproportionately to a related CPI variable. The theory employed is that of the markup-pricing model, with most equations reflecting the general form,

$$\begin{aligned} \Delta \ln(P/(1+TX)) = & a_1 \Delta \ln TX + a_2 \Delta \ln W/TFP + a_3 \Delta \ln UKC_n \\ & + a_4 \Delta \ln P_{EN} + a_5 \Delta \ln P_F \cdot PFX \\ & + a_6 \Delta KIB/KIBD + a_7 KIB/KIBD \end{aligned} \quad (14)$$

$$a_2 + a_3 + a_4 + a_5 = 1$$

where KIB and KIBD are actual and desired levels of inventories respectively. Costs include labour, capital, the price of raw materials (energy) and the price of imported goods, defined in a manner similar to RDXF. Labour costs are the average wage compensation per paid employee divided by trend factor productivity. The (exogenous) measure of TFP is obtained from estimates with a translog production function not currently employed in QFS. Capital costs are normalized according to the model-defined value of trend output. Trade prices are entered explicitly in the equations as the relevant foreign price converted to Canadian dollars by the exchange rate, thus ensuring the complete pass-through of exchange rate movements to import costs in the price equations. Of particular significance is the restriction placed on the cost coefficients in estimation, constraining them to sum to unity (i.e.,  $a_2 + a_3 + a_4 + a_5 = 1$ ).

This is in accordance with the unit elasticity contained in the model's CRS production function, and resulted in coefficients with magnitudes consistent with those implied from the 1976 input-output tables (the coefficients on energy were further constrained to equal the implied input-output values). In addition to ensuring that price is homogeneous with respect to factor costs, at least among this subset of equations, UKCs are given a significant direct role in determining price since they appear in each equation. An additional term is an indirect tax variable. As the coefficient on this variable is not significantly different from zero in most equations, a complete and immediate pass-through of indirect taxes to prices is implied.

The choice of variables to represent the influence of demand on the firm's markup reflects the view that inventories are a buffer stock, absorbing unexpected changes in demand. Deviations between current and desired stocks of inventories will result in the short-run price diverging from the long-run (optimal) price. Thus the ratio of actual to desired inventory stocks is employed, using a six-quarter moving average to reflect the presence of costs associated with frequent price changes. An increase in actual stocks relative to desired levels will exert downward pressure on prices. Since the price equations are in first-difference form both the level and change in excess demand influence price inflation. The measure of the desired stock is determined endogenously from a stock-adjustment model of inventory investment, incorporating the effect of inventory carrying costs. Since the variable for inventory carrying costs uses a short-term interest rate, an important channel is created in which monetary policy may directly influence prices. The services (excluding shelter) equation employs a different indicator of demand, since services cannot be held in inventory. Specifically, the ratio of actual to potential output (CAPU) is used.

Two CPI equations, those for food and energy, are effectively exogenous -- the former due to estimation difficulties, the latter due to the considerable influence of domestic policy. Inclusion of appropriate simulation rules associated with these variables (as is typically the case), however, produces a consumer price sector that is largely homogeneous in costs and incorporates significant demand effects. The business investment deflators employ the same cost and demand variables as the CPI equations, although an intermediate cost variable, the industry selling price excluding food and beverages, is also included. The factor-cost coefficients are again constrained to sum to one. Capital costs are somewhat less important than in the CPI equations, while import prices carry a substantial weight. The residential investment deflator is dominated by wage costs.

The significant role played by capital costs and demand variables does not, of course, remove labour costs from their position of traditional dominance in determining prices. Wages, estimated as the average wage per paid employee, are determined by an expectations-

augmented Phillips curve of the form,

$$\Delta \ln W = a_1 1/RU + a_2 \Delta \ln MH + a_3 \Delta \ln P_{CPI}^e + a_4 AIB \quad (15)$$

where MH is the average weekly hours in manufacturing. Demand in the labour market is represented by the inverse of the unemployment rate. The rate used is that for males over 25, a measure designed to minimize the impact of non-wage-related structural shifts in the labour force that have occurred historically. A second demand term, which enters with a positive coefficient, is the average weekly hours worked. An increase in weekly hours will tend to raise the wage level. The expected rate of inflation variable,  $\Delta \ln P_{CPI}^e$ , is a monotonically declining distributed lag of the four-quarter growth rate in the CPI. The sum of the lags, however, is less than unity (approximately 0.88), implying some degree of money illusion on the part of wage earners (as  $a_3$  effectively equals 1).<sup>9</sup> The influence of the Anti-Inflation Board from the fourth quarter of 1975 to the third quarter of 1978 is captured by a dummy variable.

Capital costs are based on essentially the same theory as in the RDXF model, employing the investment deflators as indicators of the price of investment goods. However, on the basis that current capital costs are dependent on past investments, each user-cost variable has been weighted by the actual flow of investment that occurred at those rates. Furthermore, with the intention of maintaining consistency with the investment equations in QFS, they have been calculated over six or seven years. One implication of this approach is that capital costs are rendered less sensitive to short-run fluctuations in explanatory variables, including interest rates and investment prices. With respect to traded prices, it has already been noted that the exchange rate enters the price equation directly as part of the import price term. The exchange rate equation in QFS incorporates a purchasing-power-parity term, expressed as the ratio of domestic ULCs to U.S. ULCs. The long-run coefficient on the term is constrained to one, with the adjustment 95% complete after three years. However, since the transmission of price increases to wages, and therefore ULCs, through the expectations term is incomplete, movements in the exchange rate will not be proportional to domestic price movements.

In summary, QFS displays some of the requirements for an accelerationist model. In particular, prices reflect a substantial degree of homogeneity with respect to factor costs (if exogenous prices are endogenized via appropriate simulation rules). The exchange rate contains complete purchasing power parity with full pass-through to the price

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9. More recent versions of QFS incorporate lags on expected inflation that sum much more closely to one, effectively eliminating money illusion. The comments in this paper refer to the version available at the time of original writing.

equations ensured. A certain amount of long-run money illusion exists in the wage equation (in this version of QFS), however, which is one factor preventing an unstable wage-price spiral (within the system).

### 4.3 FOCUS (Institute for Policy Analysis)

The FOCUS (FOreCasting and User Simulation) model, similar in size to RDXF and QFS, incorporates several unique features in its price-wage sectors. Two alternative methods are available for determining what is defined as the "key" price variable in the model. The key price series, the implicit price index for privately produced GNP, serves as the primary basis on which the remaining price variables are specified. The first available option is a neoclassical "market-clearing" regime in which a value for P is selected that equates supply and demand for aggregate output within the model.<sup>10</sup> This produces a "perfectly flexible" price level that responds to all the determinants of supply and demand (for example, P will respond to changes in labour costs and the price of capital goods, as well as to variations in aggregate demand). The speed of response of this type of process is unrealistically high, however, at least in the short run. The available alternative, which incorporates a more sluggish reaction, is the more familiar markup regime in which the key price variable is determined by a behavioural equation including cost and excess demand factors. The estimated equation is of the form

$$\begin{aligned} \Delta P = & a_1 \Delta(\text{ULC}_n + \text{UTX}_n) + a_2 \Delta \text{UPm}_n + a_3 \Delta(\text{ULC} - \text{ULC}_n) \\ & + a_4 \Delta(\text{UTX} - \text{UTX}_n) + a_5 (\text{KIB}/\text{SALES} - \text{TREND}) + a_6 \Delta P_{\text{EN}} \end{aligned} \quad (16)$$

where KIB/SALES represents the inventories-to-sales ratio and TREND its trend value (which increases with time). The principal costs are unit labour and tax costs, with an estimated average "markup" of 22% (i.e.,  $a_1 = 1.22$ ). Both variables are normalized; ULCs by employing a concept of "normal" (or trend) productivity (defined as a time trend with a "break" in productivity in the 1970s) and UTXs by taking a four-quarter moving average. The deviations of actual costs from normal unit costs are included as additional regressors (coefficients  $a_3$  and  $a_4$ , both positive). The effect in the case of ULCs is to reduce margins temporarily, with the full markup of unit labour costs requiring five quarters. Tax increases, on the other hand, are passed through almost immediately. The coefficient on unit import prices (again normalized with a four-quarter moving average) is small (0.10), but since P is the deflator for domestic production the impact of imports is felt only

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10. Output demanded is real private domestic demand at factor cost while supply output is defined using a Cobb-Douglas production function approach.

through their capacity as intermediate inputs. The remaining cost factor is the price of crude petroleum, which serves as a proxy for energy prices in general and possibly for some raw materials. Excess demand is represented by the deviation of the inventory-to-sales ratio from its trend value (defined as the average value over the estimation period with a small positive time trend). The higher the ratio relative to its trend value the lower will be the price markup.

The key price variable is subsequently employed as the principal determinant of the remaining deflators. The general form of the consumer expenditure deflators is

$$\begin{aligned} \Delta P_c = & a_{11} \Delta P + a_{12} \Delta P_m + a_{13} \Delta (TX_i - TX) \\ & + a_{14} \Delta (P_{c_{US}} - P_{US}) \end{aligned} \quad (17)$$

where  $TX_i$  is ad valorem taxes per unit of GNP in category  $i$  and  $P_{c_{US}}$  the price deflator for consumer durables in the United States. The first two factors represent the relative impact of domestic costs and import prices in the final demand deflators. The third term, found only in the durables and services equations, reflects the impact of differing relative tax burdens on different categories of final demand. The final term, found only in the durables equation, measures the extent to which sectoral prices in the United States deviate from the general price level. The intent is to capture the sectoral effects of import pricing, and to a lesser extent foreign supply and demand conditions for that sector. Once the consumer deflators are determined, a linking equation then generates the CPI from the component series (with close to unit elasticity). The CPI is incompletely determined by the consumer deflators, however, requiring two exogenous CPI series for food and gasoline. Under simulation the CPI for food is normally endogenized by allowing it to grow at the same rate as the overall consumption deflator. Note that the conventional mortgage rate is included as an additional variable in the CPI link equation. This is because the mortgage rate, while affecting the CPI, is absent from all the GNP deflators.

The residential and business investment equations are of the same general form as the component price equations for consumption. Once again the importance of both actual and potential import competition is apparent, reflected in the key role played by the U.S. relative-price-differential term in the machinery and equipment category. The business investment equations also include additional terms (specifically, the ratio of demand in the category to total private GNP) in an effort to

capture the effect of exceptional demand pressure.<sup>11</sup>

The "key variable" approach is also used to determine wages. The key wage rate in FOCUS is the average annual wages and salaries per employee in the private sector (in four-quarter per cent change form). It is determined on the basis of an extended Phillips curve, with a somewhat different interpretation placed on the role of prices. The general form is

$$\begin{aligned}\dot{W} = & b_0 + b_1 (RNU/RU) + b_2 \Delta(RNU/RU) + b_3 (\dot{P}_{FD} - \dot{P}_{CPI}) \\ & + b_4 \dot{P}_{CPI}^e + b_5 \dot{P}_{CPI} + b_6 (\dot{P}_{CPI} - \dot{P}_{CPI-1}^e) \\ & b_4 + b_5 = 1.\end{aligned}\tag{18}$$

Excess demand in the labour market is defined as the ratio of the (exogenous) natural rate of unemployment to the actual rate. Disequilibrium in both a stock and flow sense is captured as the labour gap enters in both level and level change terms. A variable indicating the difference between the rates of growth of producer output prices and consumer prices is also included. As in the RDXF model this is designed as a measure of the willingness of employers to pay wage increases. The more interesting features of the wage equation in FOCUS are located in the CPI terms. The specification allows some fraction ( $b_4$ , approximately 0.5) of expected inflation to be incorporated into current wage settlements. A second portion of wage settlements ( $b_5$ ) is adjusted to actual price movements (both current and historical due to the use of a moving average). The two fractions are constrained to sum to one, allowing for a "complete" pass-through of price movements to wage. This approach would effectively be little different from the more common single-expectations term based entirely on lagged prices (although the interpretation would certainly differ) were it not for the manner in which expectations are formed. A series of "synthetic" price expectations is obtained by regressing actual future rates of inflation (as of past dates) on a set of explanatory variables that are believed to be those that market participants actually base expectations upon, and then simulating the estimated equation. The explanatory variables include past movements in domestic prices, U.S. prices, the exchange rate, the money supply, real output, and the level of unemployment. The equation is constructed such that the expected rate of inflation will generally equal the current period inflation rate if the current rate of change (or level) in the

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11. Note that by definition the weighted sum of the various component prices must equal the aggregate index represented by the key price. In simulation, an artificial variable is calculated on the implicit assumption that the key variable is correct, and that all component prices are multiplied by it.

above explanatory variables is equal to the average rate of change (or level) during the previous two years. Thus, FOCUS includes not only the possibility of temporary nonhomogeneity as expectations adjust to actual price movements with a lag, but raises the possibility of inaccurate predictions of inflation that are sustained over indeterminate periods (allowing the economy to operate off the natural rate of unemployment). To take into account incorrect anticipation of prices the final term in the wage equation is a price catch-up variable. This allows current wage settlements to be adjusted for that portion of past settlements based on inaccurate expectations.<sup>12</sup>

Note that explicit allowance is not made for capital costs in the key price equation. Import prices are constrained to grow at the same rate as a related U.S. price, adjusted for movements in the exchange rate. The pass-through of variations in the exchange rate onto import prices is high but not complete. Prices, however, have no direct influence on the exchange rate, which is determined instead by the interest rate differential and capital flows (through which prices have an indirect impact, although probably small in the short run). Thus, import prices are essentially exogenous (at least in the short run) of domestic price.

Given the exogeneity of certain CPI components and the effective exogeneity of import prices (within the price-wage-exchange rate system) FOCUS is unlikely to display accelerationist behaviour. In addition the model stresses that for neutrality to be present the adjustment mechanism for inflation in the factor price (e.g., wage) equations must not only be singular, but that expectations must ultimately be correct.

#### 4.4 DRI (Data Resources Incorporated)

The DRI model is a medium-size quarterly econometric model. Its price sector is considerably more disaggregated than those of the previous models discussed, reflecting the use of a stage-of-processing approach to pricing.<sup>13</sup> A series of "generated prices" are first constructed at the industry level. They are based on a technical relationship combining the mix of inputs used by each industry, with weights calculated from input-output data. Included are the basic factor costs, in turn

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12. This equation essentially assumes a constant rate of productivity growth. A more recent version includes productivity explicitly (based on a five-year average), allowing productivity variations to have an impact in the model.

13. A second quarterly model that employs a stage-of-processing price sector is the Conference Board of Canada's MTFM (Medium-Term Forecasting Model). Three sectors are identified: raw material prices, industry prices, and domestic demand deflators and export prices. The theory behind the industry prices and domestic demand deflators is that of markup pricing, with the markup assumed to vary with capacity utilization and labour market tightness. Costs are represented by a cost function based on a three-factor (materials, labour, and capital) Cobb-Douglas production function with CRS.

represented by other generated prices, industry prices, agricultural and energy prices, sales taxes, and measures of labour and capital cost. The labour cost component is proxied by a broad measure of unit labour cost in manufacturing.

Industry prices are subsequently determined as a weighted average of foreign and domestic (generated) prices, with weights again specified by using input-output information. The general form of the equations is,

$$\Delta \ln P = a_1 \Delta \ln P_{GP} + a_2 \Delta \ln P_F \cdot PFX + a_3 \Delta \ln CAPU / CAPUN \quad (19)$$

$$a_1 + a_2 = 1$$

where  $P_{GP}$  represents the domestic generated price, and  $CAPUN$  a measure of the "natural" capacity utilization rate. It can be seen that prices are based on a markup pricing model incorporating an excess demand term. The demand term is the ratio of economy-wide capacity utilization to its "natural" rate (a step designed to more accurately capture excess demand). The natural CAPU level is taken either as an average of past actual values, or is generated on the basis of current values of the actual and natural rates of unemployment. Foreign prices are often represented by a U.S. wholesale price index.

A second series of generated prices is calculated at the final demand level, combining both the industry selling prices and industry-generated prices. Final expenditure deflators and consumer price indices are in turn explained by the corresponding final-demand-generated prices, as well as by the relevant import price (or U.S. price times the exchange rate) and provincial retail sales tax rate where appropriate. In some investment-related deflators a measure of demand in that expenditure category is included. Therefore the general form of the final demand and CPI equations is

$$\Delta \ln (P_i / (1+TX)) = \Delta \ln P_{GPI} + \Delta \ln (P_F \cdot PFX) + \Delta \ln D_i \quad (20)$$

where  $P_{GPI}$  and  $D_i$  are the generated final demand price and level of demand in sector  $i$ . The (merchandise) trade deflators are explained by domestic industry prices and U.S. wholesale prices for the corresponding trade category times the exchange rate. In the majority of cases, however, the exchange rate enters directly into the price equations (with a lagged adjustment based on a four-quarter moving average). As with FOCUS, a purchasing-power-parity term is not present in the exchange rate equation. Thus import prices are not directly influenced by domestic price developments.

The impact of unit labour costs is felt through the industry-generated prices. The key wage rate determining those costs is average hourly earnings in manufacturing. The functional form is the familiar

expectations-augmented Phillips curve, estimated in four-quarter per cent change form,

$$\dot{W} = b_0 + b_1 \dot{P}_{CPI}^e + b_2 (RU-RNU) + b_3 AIB \quad b_1 = 1 \quad (21)$$

The coefficient on expectations is constrained to equal one, consistent with the absence of money illusion. The labour gap term is the deviation of the unemployment rate from the unemployment rate at full employment. With respect to the user cost of capital, it also enters in the industry-generated prices and is formulated on the same basis as in other models (see footnote 4).

The use of a stage-of-processing model in the price sector ensures that the entire range of factor costs appears in the price equations with coefficients consistent with the available input-output data for the economy. In particular, capital costs are assured a significant role in price determination. In addition, it is possible to ensure that the prices at the initial stages (i.e., the industry-generated prices, which are essentially unit cost measures of products) are homogeneous of degree one with respect to factor costs. However, Empey and Thadaney (1982, p. 2) note that this homogeneity property is not maintained by the equations linking the industry and consumer prices.

## 5 Four Annual Models

### 5.1 CANDIDE (Economic Council of Canada)

CANDIDE Version 2.0 is a large-scale annual model incorporating a substantial amount of industry detail. The high level of disaggregation allows for a different approach to the construction of the aggregate expenditure deflators. The determination of final demand prices consists of four steps: 1) the determination of value-added deflators at the industry level (with value-added representing the incomes of the factors of production, or factor returns); 2) conversion of these sector prices to pseudo commodity prices using the 1971 input-output tables; 3) conversion of the commodity prices to pseudo-final-demand prices using the commodity composition of final demand and a number of indirect tax rates; and 4) adjustment of these pseudo-final-demand prices for the errors that result from using a constant coefficient input-output framework.<sup>14</sup> Each industry's value-added deflator is explained primarily as a markup over

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14. See Preston and Rao (1982). The final step points out that this methodology is not without its drawbacks. The use of value-added prices, for example, assumes a fixed proportion between gross output and value-added by industry. This assumption is unlikely to be maintained in the longer run, however, as movements in relative prices will occur that will influence factor shares (causing substitution) and change value-added prices in a manner not reflected by the model.

unit labour and capital costs, supplemented by a measure of labour productivity. Import prices and the rate of growth of output are occasionally entered as additional arguments to capture variations in the markup. The general form of the deflator, estimated in annual per cent change with distributed lags on individual regressors, is therefore

$$\dot{P} = a_0 + a_1 \dot{U}LC + a_2 \dot{U}KC + a_3 \dot{L}PROD + a_4 \dot{P}_m + a_5 \dot{D} \quad (22)$$

where LPROD represents (actual) labour productivity. An important advantage that can be derived from CANDIDE's level of disaggregation is that cost variables may be defined on the basis of industry-specific, rather than economy-wide, measures. The inclusion of import prices is intended to capture their effect on the "entry-limit pricing" behaviour of domestic producers (who may deliberately set prices below the market entry price of importers) rather than their direct cost effect as inputs into the production process. Domestic prices may be constrained by import prices where foreign competition is a factor, preventing them from responding fully to domestic cost increases if import prices remain unchanged. (Where domestic inflation is completely offset by exchange rate depreciations passed entirely through to import prices, then the effect of entry-limit pricing is to affect only the initial markup rather than the potential homogeneity of the price-wage system.) The markup may also be affected by the rate of growth of industry-specific output, introduced as a very rough proxy for capacity utilization pressure.<sup>15</sup> In estimation no restrictions were imposed on the sum of the elasticities for factor costs. In a large number of cases, however, the price response to variations in costs approaches unity in the long run. The aggregate value-added deflator exhibits an elasticity of 0.93 with respect to labour and capital costs, and the price of traded goods.

Domestic commodity prices are subsequently weighted with import prices to produce a set of commodity prices that reflect the cost of supplying goods whether produced domestically or imported, i.e.,

$$P = a_{10} P_D + (1-a_{10}) P_m. \quad (23)$$

These prices are then adjusted for various tax items and translated from a commodity-accounting framework to a set of (pseudo) prices that are in a final demand expenditure framework. The pseudo-final-demand prices are then used to derive actual final demand prices associated with consumption, investment, inventories and government spending by way of

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15. The specification described applies primarily to commercial sector deflators. The specification for noncommercial industries, where output is measured in terms of labour input, is of the form of wage equations and therefore influenced by inflation expectations and measures of labour market tightness.

regression techniques. There are some cases (e.g., several consumption deflators) where industry prices are introduced directly into the final demand equations in order to increase the pass-through from domestic industry prices. The CPI is in turn a weighted average of the final demand deflators associated with consumption items and of the home ownership price index (which is based upon construction costs, property taxes and an average of mortgage rates).

Wages are modelled at the industry-specific level as well, with the aggregate wage determined as a weighted sum of the sectoral wage rates. Two recurring macro variables appear in the equations, inflation expectations and a measure of labour market tightness, reflecting an expectations-augmented Phillips curve. Two additional sector-specific variables, productivity growth and the rate of change of the wage rate in that sector in the United States, appear in the wage rates of a few industries. The general form is

$$\dot{W} = b_0 + b_1 \dot{P}_{CPI}^e + b_2 1/RU + b_3 L\dot{P}ROD + b_4 \dot{W}_{US} \quad (24)$$

Note that the dummy variable normally used to represent the effects of the AIB is absent, as the estimation period is to 1975 only. As in QFS, the excess labour demand variable is the inverse of the prime age (25 to 54) male unemployment rate, used to offset the effect of substantial structural shifts in unemployment. The price expectations variable is constructed to describe a more "rational" process than a distributed lag on past inflation. The past year's (CPI) inflation rate and the past two years rate of growth in the money supply (M1) were combined as a weighted average.

$$\dot{P}_{CPI}^e = c_1 \dot{P}_{CPI,t-1} + c_2 \dot{MS}_{t-1,2} \quad (25)$$

The weights,  $C_1$  and  $C_2$ , sum close to unity, being 0.70 and 0.27 respectively. Given a reasonable value of  $b_1$ , this type of specification ensures that nonhomogeneity will exist in the price-wage system unless price increases are accompanied by corresponding percentage increases in the money supply. The coefficient on the expectations variable in the individual wage equations was not constrained in estimation. It was, however, almost always insignificantly different from one, although it was still possible for the actual value to stray far from unity in both directions (0.6 to 1.3 excluding the mining equation). In the aggregate wage equation the implicit coefficient is 0.95, such that the pass-through of expected prices to wages is not quite complete.

Industry-specific values for the user cost of capital (employed in unit capital costs) are calculated as in the previous models, again proxying the expected acquisition cost of capital with the final demand

deflators for investment goods obtained from the price conversion process. Import and export prices are exogenous in U.S. dollars in CANDIDE, with Canadian dollar equivalents determined by applying the exchange rate. Thus, exchange rate variations feed directly into the price equations, with the full effect being felt in the year during which they occur. The spot exchange rate is primarily determined by the expected exchange rate, which is in turn influenced by a purchasing-power-parity term. This latter term is specified as the ratio of expected domestic inflation in the CPI ( $\dot{P}_{CPI}^e$ ) to the "actual" rate of inflation (the lagged rate of growth in the U.S. GNE deflator). It is interesting to note that the CPI is employed for domestic inflation rather than a more general deflator as in other models. Its use creates a second channel through which expected inflation, as defined by equation (25), may offset the price-setting process. The expected exchange rate (and thus the spot rate) is not affected proportionately by a change in expected inflation, thus introducing a certain amount of nonhomogeneity through import prices.

The substantial amount of industry detail available in CANDIDE allows it to avoid in part the drawback found in other models of using economy-wide measures in disaggregated equations. In particular, industry-specific measures of unit labour costs are employed in the industry-price equations. The pass-through of factor costs to prices, and expected prices to wages, is not quite complete. In addition, if the money supply does not increase at the same percentage rate as the price level, then some degree of nonhomogeneity is introduced between prices and costs via the price expectations variable in the wage and exchange rate equations.

## 5.2 TIM (Informetrica Limited)

The influence of CANDIDE in the early development of TIM (The Informetrica Model) is evident in the overall structure of the model, which similarly includes a substantial amount of industry detail. There are important differences, however, in the methodology for incorporating behavioural content. Essentially, the returns to factors (i.e., wages and profits) are determined by a set of stochastic equations and then combined by a series of technical relationships into a consistent set of value-added deflators and, ultimately, final demand prices.

As with CANDIDE value-added prices are determined at the industry level, and are defined as the ratio of factor incomes in current dollars to the value-added RDP (real domestic product) measures. The wage bill (LI) for a particular sector is calculated on a per worker basis. The wage per worker,  $W$ , is essentially a function of an expectations-augmented Phillips curve. The following is a representative equation,

$$LI = N(W_{-1} + W_{-1}(b_0 + b_1 \dot{P}_{CPI}^e + b_2 1/RU + b_3 K/N + b_4 MH/N + b_5 AIB)) \quad (26)$$

where N represents employment.<sup>16</sup> The expected price variable is composed of a distributed lag including the current and previous two years. In many equations its coefficient is constrained to one to achieve full pass-through. Excess labour demand is represented by the reciprocal of the (total) unemployment rate, although it is not included in all equations. In many of these remaining equations, however, the rate of inflation in manufacturing wages (which contains the unemployment term) is included, allowing the demand for labour to have an indirect effect. Industry-specific measures will affect the wage level as well. The number of hours worked per employee will have a positive effect on wages, as will an increase in industry profits (this latter variable is not included in the representative equation). Productivity gains above the rate of inflation will also result in long-term wage gains. Productivity may be measured in two ways -- either as the capital stock per worker (shown above), or as the output per person. In both cases the variables tend to enter the wage equation with long lags. A dummy variable for the AIB is also included.

The equations for return to capital (RK), estimated behaviourally, are specified essentially on a cost-push basis.

$$RK = RDP(b_{10} + b_{11} P_K \cdot (K/RDP) + b_{12} \dot{P}_m + b_{13} \Delta(RDP/K)) \quad (27)$$

where  $P_K$  is the rental cost of capital. Essentially the return to capital per unit of output is directly proportional to the capital stock per unit of output times the rental cost of capital. The rental cost of capital is again formulated on the basis of a Jorgensonian model of investor behaviour. The impact of demand, with its subsequent effect on profits, is also included in this equation. Demand variations are represented by the rate of growth of the RDP/capital stock ratio.

As previously noted, the resulting estimates of the returns to capital along with labour costs for each industry are used in the calculation of the individual value-added prices.<sup>17</sup> In turn, the output

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16. The equations shown here are intended to be representative. The specifications for LI and RK actually reflect those of the manufacturing sector (of which industry i is a component), and therefore RDP, K and N represent the real domestic product, capital stock and employment in the manufacturing sector.

17. Within an industrial sector it is possible for the factor returns to be further allocated among individual industries via a "spreading" equation. For example, the value-added prices of the roughly twenty industries contained in the manufacturing sector are determined on the basis of

$$P_i = a_0 + a_1 (RDP_i / RDP) * LI + a_2 (K_i / K) * RK \quad (28)$$

such that the returns to labour and capital are combined, weighted by that industry's share of current-dollar RDP and fixed capital stock within the manufacturing sector.

price for each industry is a weighted average of its value-added prices and the prices of its material inputs (including imports), adjusted for industry-specific taxes. A bridge matrix input/output model is then used to define final demand prices as a weighted average of the relevant industry output deflators (and import prices). Both general and category-specific tax rates are applied where necessary. Finally, various link equations are estimated to account for error that may be introduced during the price-conversion process.

Import prices, which are included at several points in price conversion, are defined as the product of an exogenous foreign price and the exchange rate. The exchange rate does not include a purchasing-power-parity term, but rather includes the change in the real current account balance as the principal determinant. As with the DRI model, the use of technical relationships for modelling price ensures the incorporation of all factor costs (particularly capital costs) in a consistent manner. Behavioural response is confined entirely to the factor-return equations with the pricing decision essentially contained in the equations for return to capital.

### 5.3 MACE (University of British Columbia)

The MACE (MACro and Energy) model, designed to be used for both short- and long-term policy analysis, is unusual in the degree to which it is supply oriented, with particular emphasis placed on the energy resources sector. A detailed energy-producing sector is combined with an energy-using sector (basically a relatively compact non-energy macro model) with substantial attention given to the linkages between the two. The price-wage sector also contains several unique features, among them the distinction made between output and absorption prices, and the role given in general to trade prices.

MACE is based on a nested production function where capital and energy are combined in a vintage constant-elasticity-of-substitution (CES) function, and this vintage bundle is combined with labour in an outer function taking a Cobb-Douglas form with constant returns to scale. To maintain consistency with the supply framework the central price variable in the model ( $P_Q$ , output price) employs a single domestic cost variable built on a similar structure. Thus  $C_{kew}$  is specified as a CES bundle of energy and capital rental prices combined in a Cobb-Douglas function with wages per efficiency unit of labour (i.e.,  $W/LPROD$ ). The parameters from the production function are used to constrain the relative effects of the cost components. The functional form of  $P_Q$  reflects a markup-pricing model,

$$\dot{P}_Q = a_0 + a_1 \dot{C}_{kew} + a_2 \dot{P}_W + a_3 (KIB-KIBD)/KIBD \quad (29)$$

where the domestic cost and world price ( $P_W$ ) coefficients are constrained to sum to unity (i.e.,  $a_1 + a_2 = 1$ ). Thus, domestic output prices will be affected by energy prices, long-term interest rates, and wages through the domestic cost function and by foreign competition through the price of competing world products. World prices are a weighted average of a price index of world exports of goods and the U.S. absorption price, converted to Canadian dollars via the exchange rate. The effects of demand on the markup are captured by an excess-inventory term, relating actual to desired inventories. The specification of price in MACE thus conforms closely with the analysis of Nordhaus. The costs of all factors of production appear in the price equation, with their coefficients related to their factor shares. In addition price responds with unit elasticity to increases in all costs, consistent with a production function exhibiting CRS.

Workers distinguish their real wage not on the basis of output price, but on the basis of the absorption price ( $P_a$ ). The absorption price is a weighted average of the prices of domestic output and non-energy imports,

$$\dot{P}_a = a_{10} + a_{11} \dot{P}_Q + a_{12} \dot{P}_m \quad (30)$$

The coefficients,  $a_{11}$  and  $a_{12}$ , are not constrained in estimation and sum to less than one ( $a_{11} + a_{12} = 0.91$ ). The absorption price appears in the wage equation, which is constructed as a quasi-reduced-form equation producing results similar to that of an augmented Phillips curve.

$$\begin{aligned} \dot{W} = & b_0 + b_1 \dot{W}_{-1} + b_2 \dot{P}_a + b_3 \text{RNU/RU} + b_4 \dot{\text{CAPU}} \\ & + b_5 \dot{P}_x/\dot{P}_m + b_6 \text{AIB} \end{aligned} \quad (31)$$

$$b_1 + b_2 = 1$$

Expected inflation does not appear as an explicit argument in the equation, but to reflect the absence of money illusion the coefficients of the absorption price and lagged wage are constrained to sum to one ( $b_1 + b_2 = 1$ ). The level of excess labour demand is in terms of the ratio of the (exogenous) "natural" rate of unemployment to the actual rate. The unemployment rate, however, is not the only link between real activity and wage inflation, as changes in capacity utilization will also affect wages. Since CAPU represents the ratio of actual output to output at normal utilization rates with labour productivity at trend values, this variable will capture any effects of cyclical variations in factor productivity.

A somewhat novel feature is the incorporation of the terms of trade ( $P_x/P_m$ ) explicitly in the wage equation. While the coefficient,  $b_5$ , is statistically insignificant it is empirically significant, such that improvements in the terms of trade will have important positive effects on  $W$ . Import prices in MACE are based on the standard small open economy assumption, being equal to foreign prices converted to Canadian dollars. Export prices, however, include a substantial element of domestic price-setting as both the domestic output price and demand terms are included as regressors.

$$P_m = P_F \cdot PFX \quad (32)$$

$$\text{and } \dot{P}_x = a_{20} + a_{21} \dot{P}_Q + a_{22} \dot{P}_W + a_{23} PFX + a_{24} (KIB - KIBD)/KIB \quad (33)$$

$$a_{22} = a_{23}, \quad a_{21} + (a_{22} \text{ or } a_{23}) = 1.$$

World export prices enter along with the exchange rate to represent export categories exhibiting price-taking behaviour, with the constraint that the coefficients be equal. In turn the coefficients on domestic price and foreign price (either  $a_{22}$  or  $a_{23}$ ) are constrained to sum to unity, with weights of 0.68 and 0.32 respectively.

Price levels are also influenced by energy prices and the cost of capital through the domestic cost variable,  $C_{kew}$ . Energy prices are affected by a number of factors, with the refinery-gate crude oil price depending on world oil prices, oil demand by region, oil exports, and the supplies of oil from various sources. User prices are calculated by estimating margins, primarily influenced by the general rate of price inflation. The natural gas price is linked (by federal policy) to the refinery-gate crude oil price, with the margin again influenced by the rate of inflation in the absorption price. Electricity prices are assumed to grow with the general rate of inflation. Despite these endogenous elements, however, energy prices (particularly oil) still reflect a substantial proportion of regulation. The rental price of capital is, as in other models, essentially calculated as a fraction of the replacement cost of capital goods. The proxy for the current cost of capital goods is the absorption price, with the user cost affected by the rate of depreciation and the long-term bond rate.

One advantage of a small econometric model is the relative ease with which desirable dynamic properties may be obtained. Thus, the aggregate output price ( $P_Q$ ) has an elasticity of unity with respect to all factor costs, consistent with the production function. In addition, the aggregate wage rate is specified such that money illusion is not present in the long run. These two factors, plus the specification of trade prices, produce a price-wage system that is nearly homogeneous in its arguments. One factor preventing homogeneity is that wage earners bargain

on the basis of the absorption price rather than the output price, the former responding to cost increases with an elasticity of less than one. However, suppose that the exchange rate is determined purely by purchasing power parity (one of the several available options within MACE), such that

$$\ln PFX = d_0 + d_1 \ln P_Q / Pa_{US} \quad \text{where } d_1 = 1 \quad (34)$$

Then, if it is also assumed that the percentage growth rate of energy prices and user capital costs equaled that of wages, and that the coefficients in the  $Pa$  equation did in fact sum to one, then the price-wage sectors in MACE would produce completely accelerationist results (recall that we are treating the excess demand variables as effectively exogenous). In this case import and export prices would increase by equivalent amounts. If the exchange rate assumption was altered such that it was assumed to be fixed the system would remain nearly accelerationist. This is due to import prices remaining unchanged while export prices increased with domestic prices, raising the wage level through the terms-of-trade term.

#### 5.4 SAM (Bank of Canada)

SAM (Small Annual Model) has been under development for the past several years at the Bank of Canada, and incorporates a number of precepts not currently found in most macroeconometric models. Perhaps the most important feature of the model is that it explicitly identifies the long-run steady-state equilibrium values of the model separately from the equations describing the dynamic adjustment path to equilibrium. Among the variables for which long-run steady-state values are determined are the price level (specifically the steady-state consumption price index) and real factor costs (including wages, energy prices and the cost of capital).

The equilibrium condition for the consumption price level is specified on the basis of a stable demand-for-money function, such that its long-run steady-state value ( $Peq$ ) is determined by the money supply, the equilibrium nominal interest rate equal to the expected long-run real rate on government bonds plus the long-run expected inflation rate (the long-run expected growth rate of money less the growth rate of output in the steady state), and equilibrium real wealth. Thus,

$$\ln Peq = a_0 + a_1 \ln MS + a_2 (r + \dot{MS}^e - \dot{D}_{eq}^e) + a_3 \ln V \quad (35)$$

$$a_1 = a_3 = 1$$

where  $MS$  is high-powered money and  $V$  a measure of wealth (both financial and human). As  $Peq$  is a determinant of the current output price, the

level and growth rate of the money supply enter the model explicitly as long-run determinants of P. The output price, a variant of the familiar markup-pricing model, is best viewed as a model of price response to market disequilibrium, during which the short-run inflation rate will deviate from, and adjust slowly towards, its equilibrium value. It is hypothesized that the output price will respond to essentially three forces when in a state of disequilibrium. First is the natural tendency of the market price to move towards equilibrium. Second is the degree of excess demand in the economy, and third is a misperception of factor costs.<sup>18</sup>

$$\ln P = a_{11} \ln P_{-1} \cdot (1 + \dot{P}^e) + a_{12} \ln(P_{eq} \cdot REL) + a_{13} \ln(KIBD/KIB) + a_{14} \ln(SALES_n / Deq) + a_{15} (W/Weq) \quad (36)$$

$$a_{11} + a_{12} = 1$$

where REL is the steady-state ratio of the output price to the consumption price and Weq is the steady-state nominal wage. The first two terms on the right-hand side, whose coefficients are constrained to sum to one, ensure that the current price will (ignoring other market factors) lie between last year's price grossed up by expected inflation and the equilibrium price. Expected inflation is a function of current inflation and long-run inflation, being a weighted average of the expected money-growth rate less the steady-state output-growth rate. In the

$$\dot{P}^e = c_1 (\dot{MS}^e - \dot{D}_{eq}) + (1 - c_1) \dot{P}_{-1} \quad (37)$$

long run expected inflation is equal to the growth rate of the equilibrium price level. The effect of excess demand in the goods market is measured in both stock and flow terms. A positive gap between the desired stock of inventories and the actual stock of inventories, and between expected sales (a weighted average of current sales and equilibrium sales) and equilibrium sales (equal to equilibrium non-energy output), will put upward pressure on the price level. Finally, factor-market disequilibrium can influence the price-setting process, since an increase in the market wage above the equilibrium wage will push prices upward.<sup>19</sup> This aspect

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18. The relatively recent nature of SAM means that some of its equations are under development, and thus the specifications discussed here should not be taken as their final form. For example, efforts are currently underway to include a term in equation (36) that adds a direct influence of foreign prices on P.

19. Theoretically, disequilibrium in capital, energy and world output-factor markets should influence the price level in a similar manner to wages. Attempts to include these variables, however, have as yet proved unsuccessful.

of the price equation incorporates the essential feature of the markup equation, whereby higher factor costs will lead to higher prices. Note, however, that in SAM this will tend to move the market solution away from equilibrium (as  $W$  above  $W_{eq}$  will raise  $P$ , increasing  $W$  even further).

The consumption and investment prices are subsequently determined as weighted averages of the producer output and import (net of energy) prices, modified by appropriate tariff and indirect tax rates. For example,

$$\ln P_c = a_{20} + a_{21} \ln P + a_{22} \ln (P_m \cdot (1+TX)(1+TAR)) \quad (38)$$

$$a_{21} + a_{22} = 1$$

where  $TAR$  is the tariff rate. Import prices, as a function of world prices converted into Canadian dollar equivalents, reflect price-taking behaviour. Real energy prices are set exogenously in SAM.

The wage equation, based on a similar structure to the price equation, describes market disequilibrium as well. The dependent variable is specified as the real wage, with the equation taking the form,

$$\begin{aligned} \ln W/P = & b_1 \ln (W/P)_{-1} \cdot (1+W_{TR}) + b_2 \ln (W_{eq}/(P_{eq} \cdot REL)) \\ & + b_3 (RNU - RU) + b_4 (b_5 (\dot{P}_c^e - \dot{P}_c) \\ & + (1-b_5)(\dot{P}^e - \dot{P})) \end{aligned} \quad (39)$$

$$b_1 + b_2 = 1$$

The first three terms again measure the stabilizing influence of the natural tendency for the wage to seek its equilibrium level (i.e., the wage rate consistent with full employment).<sup>20</sup> The current wage will lie between last year's real wage grossed up by the trend growth rate of real wages,  $W_{TR}$ , (equal to productivity growth) and the equilibrium real wage. When all markets are in equilibrium the nominal wage grows with actual inflation, and the real wage grows with productivity growth. When markets are in disequilibrium wages are influenced by the labour gap, measured as the difference between the (exogenous) natural unemployment rate and the actual rate. In addition, errors in inflation expectations influence

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20. The equilibrium wage rate is constrained to be consistent with full employment according to an equilibrium labour supply function. Armstrong (1983) notes that given a production function with CRS and assumptions about the perfectly competitive nature of factor markets, it is possible to solve for the steady-state real wage as a function of only the steady-state prices of capital and energy using the model's production technology. The equilibrium wage is then determined by grossing up the steady-state wage (in real efficiency units) with labour productivity and multiplying by the equilibrium price.

wages directly. Inflation errors by both consumers and producers are included, since if labour has an "ex post high" expectation of inflation they will tend to raise their wage demands, and if business also has an "ex post high" expectation of inflation they will tend not to resist labour's demands.

SAM is particularly interesting in that it makes explicit the macro link between money and prices within the price-wage system (beyond the inclusion of money growth in inflation expectations as is done in several models). A stable demand-for-money function implies a macro restriction on the relationship between the price level and the money stock, recognized in SAM through the concept of  $P_{eq}$ . The price dynamics imposed by  $P_{eq}$  ensure that this restriction will ultimately be observed as the solution converges to an equilibrium. If money growth increases,  $P_{eq}$  will rise above  $P$  and continue to do so until both actual and expected inflation are driven up to the new equilibrium level. The impetus comes from the gap implicit between the first two terms in equation (36). Similarly, if expectations change for exogenous reasons in a manner inconsistent with monetary policy, the initial effect on the price level is to again open a gap between  $P$  and  $P_{eq}$  that will control the divergence.

## 6 Full-Model Price Response

The preceding discussion has dealt with the determination of prices within the price-wage sectors, and the extent to which they exhibit accelerationist characteristics. However, as stressed earlier, it is only in the context of a full macro model that the complete price response may be viewed. To this end I compare the response of the eight econometric models to three shocks, two financial and one real.<sup>21</sup> Some of the features contained in the individual price-wage sectors that influence the full-model dynamics are indicated. In addition, emphasis is placed on the behaviour of real wages.

### 6.1 Interest Rate Shock

Table 1 displays the results from a permanent 100 basis point reduction in short-term interest rates, facilitated in most models by a steady increase in the money supply (see the appendix for mnemonic definitions). There are three principal channels through which the impact

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21. The simulation results are obtained from shocks performed for the Seminar on Responses of Various Models to Selected Policy Shocks held at the Bank of Canada in July of 1982. Some of the models will have undergone significant revision since this seminar and may provide significantly different results today. A complete discussion of the full-model dynamics behind the results is beyond the scope of this paper. Readers wishing more complete coverage of the mechanics involved may refer to the individual papers written by the modellers, or to the summary contained in O'Reilly, et al. (1983).

Table 1

100-Basis-Point Reduction in Short-Term Interest Rates  
(per cent change, shock minus control)

Quarterly Models

	RDXF			QFS			FOCUS (2)			DRI		
	1	3	10	1	3	10	1	3	10	1	3	10
UGNE	.26	.55	.59	.19	.46	.24	.42	2.55	4.53	.09	.30	.21
RU(1)	-.09	-.38	-.17	-.07	-.41	-.20	-.09	-.93	-1.48	-.03	-.21	-.03
PGNE	.12	.97	4.46	.08	.89	3.48	.14	1.70	11.20	-.07	.49	.44
PCPI	.15	.96	4.31	.22	1.04	3.35	.31	2.27	9.82	.08	.59	.31
W	.04	.94	5.02	.02	.60	3.55	.28	2.15	13.88	.00	.50	.77
PFX(1)	.010	.027	.070	.02	.04	.07	.016	.075	.184	.01	.03	.01
YDP	-.01	.87	3.95	-.12	.87	3.08	.31	3.09	14.52			
YC	2.92	4.52	9.03	4.87	3.68	10.61	2.52	12.67	19.76	.77	3.44	.93

Annual Models

	CANDIDE			TIM			MACE (3)			SAM		
	1	3	10	1	3	10	1	3	10	1	3	10
UGNE	.00	.25	.25	.24	.41	.80	.24	.45	.60	.35	.07	-.14
RU(1)	-.02	-.01	.10	-.06	-.15	-.23	-.05	-.12	-.04	-.09	-.07	-.08
PGNE	.20	.43	.01	.18	-.27	-.98	-.12	.16	1.16	.62	2.83	11.18
PCPI	.24	.41	-.13	.14	-.33	-1.02	-.04	.23	1.14(4)	.85	3.36	12.13
W	-.00	.57	.44	.12	-.19	-.72	-.04	.14	1.21	.61	2.58	10.44(5)
PFX(1)	.008	.011	.002	.009	.008	.002	.007	.011	.021	.00	.02	.06
YDP	-.18	.16	-.24									
YC	3.87	3.66	-.44	3.99	3.58	2.59	.39	1.48	2.91			

(1) level change (2) markup price rule  
(3) 75-basis-point reduction in 1- to 3-year rate with interest rates endogenous  
(4) absorption price (5) unit labour costs

on price may be felt. A depreciation of the Canadian dollar and an increase in interest-sensitive expenditure will put upward pressure on domestic prices via the price of traded goods and excess demand variables. Lower interest rates will also have a downward influence on prices through lower costs, both directly (e.g., lower mortgage rates) and through capital cost terms.

Two models, FOCUS and SAM, exhibit a very strong price-wage spiral, accompanied in the former model by large increases in output. The reason for the spiral in FOCUS appears to lie outside the specification of the price-wage sector (which for the purposes of the simulations shown employs the markup-price option). Rather, a primary cause is the high sensitivity of the exchange rate to international capital flows, which are highly mobile in the model. Larger and larger depreciations are required to balance capital flows, which in turn feed prices. In addition, price expectations are positively influenced by movements in the money supply, exchange rate, output and the level of unemployment, contributing to particularly strong wage increases. Finally, as capital costs do not appear in the "key price" equation there is no restraining influence from this channel. In SAM capital costs do not have a direct effect on the price equations either, which include only disequilibrium in labour markets (and therefore wage costs) and not disequilibrium in capital markets. Note that if the shock is to real rather than nominal interest rates, the "explosive" price-wage spiral in both FOCUS and SAM is eliminated.

Aside from FOCUS and SAM, the models with the strongest response in the price level are RDXF and QFS, followed at some distance by MACE. The price-wage sectors of these models demonstrate substantial accelerationist characteristics. In particular, both RDXF and QFS employ exchange rates that exhibit long-run purchasing power parity with U.S. prices (MACE employs a portfolio model for these simulations). This is reflected in a steady depreciation in both models, applying considerable upward price pressure through traded prices. In addition, the price sector of RDXF has weak direct effects on prices from declines in capital costs. They play a much larger direct role in QFS and MACE, given the constraints on the cost coefficients present in both models. This downward influence may be at least partially offset, however, by the use of interest-sensitive desired inventories in the excess demand terms of both QFS and MACE (lower interest rates raise the desired level of inventories, lowering the inventory gap and signalling higher demand).

The three models (DRI, CANDIDE and TIM) whose price sectors are based on input-output models show the least response in the price level. The input-output approach to modelling ensures that capital costs play a significant role in price formation. This is most readily seen in TIM, where prices fall steadily after the first year until they are 1 per cent below control in year 10. This in turn is partly responsible for the extremely strong increase in output (UGNE), which is insufficient to stem

the downward trend in prices. In DRI and CANDIDE the price response peaks relatively early and then also declines during the latter years of the simulation.

With respect to real wages (defined as  $W/PCPI$ ) a general pattern clearly emerges. After an initial decline in the real wage, nominal wage increases eventually catch up and exceed price increases in most models (the exception is SAM, in which the real wage steadily declines). This pattern is not surprising given the lags involved, as upward pressure on wages through labour market tightness and price expectations take longer to develop in the short run, and longer to abate in the long run. A permanent increase in the real wage would not be unexpected, however. The wage equations in most models eventually react to price increases with close to unit elasticity. The price equations, on the other hand, tend to contain incomplete pass-through of costs, with some prices exogenous. This would tend to bias downward the response of prices relative to wages. In QFS, where the price elasticity in wages is only 0.88, while costs are constrained to enter prices with an elasticity of 1.0, the decline in real wages in the initial years is among the strongest while the subsequent increase is relatively weak.

Variations in real wages (and real factor returns generally) will have a multitude of effects in a complete macro model, not the least of which is the impact on income distribution. Increases in real wages not accompanied by coincident increases in labour productivity will tend to reduce profit levels (YC). It is the increase in output and in output price that tends to dominate the initial response of profits, however, which surge sharply in the short run. It is also apparent that the results depend on the specification of the income distribution sector. In RDXF and QFS, where the discrepancy between income and expenditure is allocated to profits, increases in real wages do not prevent a continuing increase in profits as nominal income rises. With the exception of FOCUS and SAM, however, the remaining models tend to show a pattern where stronger increases in the real wage (in order -- CANDIDE, DRI, TIM and MACE) lead to lower increases in corporate profits.

## 6.2 Money-Growth Shock

A shock similar to the interest rate shock just described is a one per cent reduction in the growth rate of the money supply. As this generally entails an increase in interest rates the transmission mechanism remains essentially the same (but opposite in direction), although the interest rate increases required to permanently reduce the rate of growth of the money supply vary substantially across the models (see Table 2). This shock is useful in demonstrating the degree to which prices respond proportionately to money over the longer term. Note, however, that within the context of a full model non-homogeneity may be introduced (appropriately) from a number of sources. The modellers of SAM, for

Table 2

1 Per Cent Reduction in the Money Supply Growth Rate  
(per cent change, shock minus control)

Quarterly Models

	RDXF				QFS				FOCUS (2)				DRI			
	1	3	10	10g	1	2	10	10g	1	3	10	10g	1	3	10	10g
UGNE	-.10	-.64	-.86	-.08	-.07	-.19	-.58	.01	-.09	-0.75	-2.13	-.38	-.16	-.62	-1.13	-.06
RU(3)	.03	.40	.35		.02	.15	.79		.03	.40	.98		.06	.58	.64	
PGNE	-.00	-.61	-4.57	-.77	-.03	-.19	-4.85	-1.00	-.12	-1.44	-7.09	-.96	.16	-1.34	-4.62	-.19
PCPI	.00	-.59	-4.41	-.67	-.09	-.31	-4.74	-.90	-.16	-1.58	-6.35		-.17	-1.95	-5.38	
W	.00	-.52	-5.10		-.01	-.08	-4.78	-1.00	-.10	-1.19	-7.32		-.03	-1.52	-6.77	
PFX(3)	-.004	-.023	-.076		-.01	-.02	-.11		-.005	-.036	-.109		-.02	-.08	-.20	
r(7)	.48	.93	1.56		.39	.66	1.67		.22	.31	.51		1.80	2.98	12.59	
YC	-.90	-4.38	-10.39						-1.00	-6.22	-11.57		-1.32	-9.30	-18.38	

Annual Models

	CANDIDE				TIM				MACE (4)				SAM (4)			
	1	3	10	10g	1	3	10	10g	1	3	10	10g	1	3	10	10g
UGNE	-.02	-.38	-2.0	-.05					-.31	-1.24	-2.73	-.38	.00	-.04	-.03	.00
RU(3)	.07	.14	-.09						.07	.33	.22		.01	.03	.06	
PGNE	-.44	-1.44	-3.30	.21					.16	-.23	-5.40	-.65	-.03	-.63	-7.61	-1.23
PCPI	-.53	-1.56	-2.78						.05	-.47	-5.27(5)		-.01	-.73	-8.36	
W	-.00	-.96	-4.55						.05	-.25	-5.31		-.05	-.65	-7.46	-1.27(6)
PFX(3)	-.016	-.041	-.081						-.009	-.032	-.097		-.001	-.004	-.040	
r(7)	.96	2.18	7.82						.93	1.64	2.51		-.41	-.61	-.93	
YC	-6.20	-11.88	-8.39						-.52	-3.69	-13.90					

(1) change in growth rate after 10 years (2) markup price rule (3) level change (4) high-powered money  
(5) absorption price (6) unit labour costs for level change, wage rate for growth rate change  
(7) level change in percentage points

example, cite several reasons why this would be expected in their model, including induced changes in desired inventories, variations in the real rate of taxation on equities, and the supply response in the labour market.<sup>22</sup>

Notwithstanding the potential for non-neutrality, in the tenth year of the shock the rate of growth in the price level is roughly one per cent lower in five (QFS, FOCUS, RDXF, SAM and MACE) of the seven models for which results are available. Of the five, the downward shift varies from -0.65 per cent for MACE to -1.23 per cent for SAM. In all the models adjustment to steady state is not completed, with output growth still affected in some (MACE and FOCUS) and overshooting in others (SAM). As with the interest rate shock the price-wage (per cent level) response is strongest in FOCUS and SAM, although considerably closer to that of the other models in this case. The relatively small increase in interest rates in FOCUS assists in keeping the exchange rate appreciation (and its effect on prices) in line with that of other models. Contributing to the large price response in FOCUS, however, is the presence of the money supply in the price-expectations equation. SAM also includes the money supply directly in the price-expectations variable. Its downward influence is further felt, however, through the impact of the money supply on the equilibrium price, which is specified on the basis of a demand-for-money function.

The two models (DRI and CANDIDE) with input-output-based price sectors required the largest interest rate increases to achieve the reduction in money growth. The DRI model produced a price-wage response similar to that of the RDXF, QFS, MACE group of models (unlike the interest rate shock). Although the very large increase in interest rates would have a significant direct upward impact on prices, it appears to have been largely offset by the large appreciation created in the dollar. It is primarily due to exchange rate effects that the model diverges substantially from price neutrality in the long run. The interest rate effects on prices are more apparent in CANDIDE. Although the money supply enters directly into the model's price expectations term, the large increase in interest rates contributes to the smallest decline in the price level among the models. As with the DRI model, CANDIDE does not indicate a homogeneous price-inflation response after ten years.

The pattern that emerges with respect to real wages is similar to that found in the interest rate shock (but again opposite in direction). Real wages initially increase due to the lagged response of wages, but eventually fall as expectations adjust and the wage response surpasses that of price. Note that in most models nominal interest rates must rise continuously to constrain money growth even though prices decline. The loss in output (and higher unemployment rates) sustained in all the models after ten years, created for the most part by the increase in real

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22. See Rose and Selody (1982, pp. 11-13) for an elaboration.

interest rates, creates the possibility of a permanent loss in real wages. The two models (QFS and SAM) that reported the change in the growth rate of wages indicate a response very close to that of price inflation -- a result not unexpected given that wages tend to react to prices with near unit elasticity.

### 6.3 Expenditure Shock

Table 3 describes the response of the models to a \$1 billion increase in federal Government non-wage expenditure (sustained in real terms). In most cases monetary policy is non-accommodating, requiring increases in short-term interest rates to maintain the money supply at or near its control value. The initial increase in domestic expenditure creates upward price pressure through the excess demand terms. Higher expected inflation, combined with a reduction in the labour market gap, stimulates wage growth which further augments the price response. The increase in demand tends to decline in the latter years of the shock, reducing inflationary pressures.<sup>23</sup>

Restricting growth in the money supply holds special implications for some models. In CANDIDE it reduces the pass-through of prices to wages from 0.92 to 0.66, due to the presence of the money supply term in the price-expectations variable. However, the relatively strong role that the cost of capital plays in CANDIDE implies that this is at least somewhat offset by the increase in interest rates. Higher capital costs combined with a strong output response result in price increases that are among the largest of the eight models. Another model whose price sector is based on an input-output model exhibits price increases that are among the weakest. Prices in TIM are only 0.35 per cent higher after ten years, as opposed to 0.95 per cent in CANDIDE. Monetary accommodation in the TIM simulation prevents any increase in interest rates, which, on the basis of the previous shock, would be expected to have a strong positive effect on price. Additionally, the strong increase in domestic output provides further indication that the response of TIM to excess demand (which is confined to the factor-return equations) is relatively low. Note that in both TIM and CANDIDE the cyclical increase in productivity from the shock actually reduces prices in the short run. The DRI model has an extremely strong short-run response, but a long-run response that is average, indicating little conformity among the input-output-based models to this type of shock.

The three models which have strong accelerationist characteristics, QFS, RDXF and MACE, all show reasonably strong price responses. In RDXF and QFS the response is somewhat muted by the fact that the interest rate

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23. For example, in QFS real GNE remains significantly above control in the tenth year. However, a reversal of the inventory gap and the increase of the unemployment rate above its control value means that the excess demand terms are exerting downward pressure on prices and wages.

Table 3

\$1 Billion (Constant) Dollar Increase in Federal Non-wage Expenditure -- Monetary Policy  
Non-Accommodating  
(per cent change, shock minus control)

Quarterly Models													
	RDXF			QFS			FOCUS <sup>(2)</sup>			DRI			
	1	3	10	1	3	10	1	3	10	1	3	10	
UGNE	.28	.14	.01	.32	.38	.14	.29	.33	.17	.33	.27	.24	
RU(1)	-.11	-.10	.03	-.12	-.27	.02	-.07	-.15	-.03	-.15	-.21	-.14	
PGNE	.01	.19	.48	-.02	.09	.61	.03	.21	.28	.02	.47	.64	
PCPI	.06	.22	.48	-.01	.08	.56	.04	.19	.21	.05	.33	.55	
W	.05	.35	.65	.01	.11	.82	.06	.27	.39	.02	.28	.68	
PFX(1)	-.00	-.001	.004	-.00	-.00	-.00	.004	.004	.003	.01	.01	.02	
YDP	.22	.48	.73	.16	.45	.80	.16	.42	.40				
YC	1.50	.23	-.03	3.12	-.20	1.80	1.51	1.30	.62	1.13	2.08	2.35	
Annual Models													
	CANDIDE			TIM <sup>(3)</sup>			MACE			SAM <sup>(5)</sup>			
	1	3	10	1	3	10	1	3	10	1	3	10	
UGNE	.55	.60	.16	.46	.43	.28	.18	.05	-.18	.13	.06	-.05	
RU(1)	-.25	-.37	-.17	-.14	-.28	-.37	-.04	-.03	.01	-.01	-.04	.02	
PGNE	-.05	.14	.95	-.05	-.02	.35	.14	.36	.71	.11	.44	.94	
PCPI	-.02	.19	.89	-.02	.01	.32	.09	.26	.62(4)	.16	.59	.90	
W	.01	.18	1.02	.09	.04	.37	.10	.37	.59	.05	.32	.90(6)	
PFX(1)	.003	.003	.005	.001	.002	.004	-.003	-.005	.005	.00	.00	.01	
YDP	.32	.63	1.91										
YC	2.58	2.38	1.63	2.18	1.87	1.52	.72	.20	.07				

(1) level change (2) markup price rule (3) accommodating monetary policy  
(4) absorption price (5) bond financed, some monetary accommodation (6) unit labour costs

increases prevent their exchange rates from depreciating in accordance with purchasing power parity. This effectively exogenizes most traded prices in the two models. Price increases in SAM are among the strongest, despite a relatively low percentage increase in demand. The relatively small increase in output is in part due to the fall in real wages which curtails consumption. In SAM the demand effects on price are not fully passed through to wages, in part due to expectations errors, allowing a large gap between wages and prices to open up in the medium term. Real wages in the remaining models, after small declines in some cases, tend to show positive increases throughout the simulation period. This is again not surprising as the pass-through of price to wage tends to be more complete than the reverse, and wages react reasonably strongly to increased labour market tightness. This appears to be particularly true in FOCUS, where the impact of demand variations are felt not only through the excess demand terms, but through the output and unemployment terms in the price-expectations variable. Thus, because of a relatively small response in the absolute price level, FOCUS produces one of the largest increases in real wage rates.

## 7 Conclusion

We have reviewed the price-wage sectors of eight Canadian macroeconometric models and the theory of price determination contained therein. The current empirical view of the determinants underlying the short-run price-adjustment process has been identified through examination of the functional form of the price and wage equations in each model.<sup>24</sup> Essentially, they tend to follow the general form of the markup price equation and augmented Phillips curve wage equation described in Section 2. This is not to say, however, that important differences in approach do not exist among the models.

The price equation is generally specified as a markup over costs, among which wages retain their traditional dominance. There is an increasing tendency, however, to investigate the role of other cost variables, particularly capital costs and energy prices. Given the degree of openness of the Canadian economy import prices also play an important role among costs, although several models stress their effect upon entry-limit pricing. In some cases (e.g., QFS, MACE, and the DRI model) the elasticity of prices with respect to total costs is constrained to be one. In other models where this constraint is not imposed the pass-through of costs is generally near, but less than one (e.g., 0.93 in CANDIDE and 0.97 in RDXF). While the capacity utilization rate (or

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24. Note, however, that all the models are subject to revision and current versions may differ from those described here. For example, as noted in the text, the wage equations of FOCUS and QFS, and the output price equation of SAM have been altered since the time of original writing.

suitable approximation) has traditionally been employed to capture excess demand in the goods market, it is interesting to note that several models (QFS, MACE and SAM) now utilize the divergence between actual and desired stocks of inventories as the appropriate measure.

Substantial support for the absence of money illusion on the part of wage bargainers is indicated in the wage equations. While this property is imposed in most models (RDXF, FOCUS, MACE, SAM, and the DRI model), in CANDIDE where the elasticity with respect to prices is freely estimated in a large number of disaggregated equations, the implicit aggregate coefficient is very close to one (0.95). In QFS the elasticity is lower, but still high (0.88). The price-expectations variable is usually specified as a distributed lag on past prices, with the sum of the lagged coefficients almost always summing to one. In some cases (CANDIDE, SAM and FOCUS) modellers have attempted to define a more rational process by incorporating changes in the money supply. FOCUS includes a number of additional determinants (e.g., the exchange rate) that agents are believed to base their expectations upon, creating further potential for substantial errors in expectations. Excess demand in the labour market is often represented by the reciprocal of the unemployment rate (usually covering a subset of the working population to minimize the impact of structural changes). However, several models employ the deviation of the actual from the "natural" unemployment rate, although this creates the obvious difficulty of defining the natural rate.

The equations in SAM present a rather unique approach. The price and wage equations are specified to capture the response to market disequilibrium, with the steady-state equilibrium values of prices and wages explicitly modelled in separate equations. The steady-state equilibrium condition for prices is specified on the basis of a stable demand-for-money function, while the equation for actual prices incorporates the tendency to move towards this equilibrium. Thus SAM makes explicit the macro link between money and prices (beyond the inclusion of money growth in inflation expectations) within the price-wage system. This does not preclude, however, retention of the more traditional elements of costs and excess demand in the equations.

There appears to be increasing attention paid by modellers to the implied constraints on the long-run determination of prices arising from the specification of the model's production technology. In QFS the elasticity of price to costs (including capital costs) is constrained to one, consistent with that model's CRS production function. In MACE, specific use is made of the production-function form and parameters to constrain the relative effects of the cost components. One implication of this type of approach is that capital costs have a significant direct role in price equations, a feature that has often been difficult to establish empirically. The stages-of-processing, input-output approach to modelling the price sector (employed by TIM, CANDIDE and DRI) also ensures that capital costs are present in a significant manner. It is notable that in

the interest rate reduction shock described in Section 6 these three models displayed the weakest positive (sometimes negative) price response. Capital costs are specified similarly in most models, based upon Jorgensonian rates of return with significant potential for money illusion (at least in the short run).

The substantial degree of homogeneity among the price and wage equations creates the potential for a large degree of inertia in the price-wage process, and, in the extreme case, accelerationist price behaviour. This is moderated in the short run by the presence of lags in the adjustment process, which are quite significant in all the models (an exception would be the flex-price option in FOCUS). With the possible exception of SAM, none of the models display accelerationist results in the long run as a result of the specification of their price-wage sectors, due to the partial or complete exogeneity of some prices (particularly energy and food), or the presence of money illusion in factor prices. It is possible that import prices may serve as an anchor to the long-run price-determination process (within the price-wage system) if the exchange rate responds less than proportionately to domestic price increases. Several models (e.g., RDXF and QFS), however, contain purchasing-power-parity terms in their exchange rate equations which ensure a proportional response on the part of import prices. Note that the accelerationist potential in MACE is retained in a fixed exchange rate regime, due to the inclusion of the terms of trade in the wage equation combined with a substantial domestic influence on export prices.

The empirical approach taken by the modellers thus generally reflects a neo-Keynesian view, with a high degree of price-wage inertia present, an important role to be played by excess demand, and substantial lags in the price-adjustment process. The influence of significant rigidities is evident in the evolution of real wages in the simulations described in Section 6. Prices respond more strongly initially, while wages react less quickly, thus opening up a real wage gap. As expectations adjust, wages eventually match and surpass the movement in prices.

## APPENDIX

### Variable Mnemonics and Description

#### Symbols:

- per cent change (either  $(x-x_{-1})/x_{-1}$  or  $(x-x_{-1})/x_{-1} \cdot 100$ )
- e expected value
- n normalized value

#### Variables:

AIB	dummy variable for the Anti-Inflation Board
CAPU	capacity utilization
CAPUN	"natural" rate of capacity utilization
D	level of demand (expenditure)
DEG	excess demand in the goods market
DEL	excess demand in the labour market
Deq	equilibrium level of demand
K	capital stock
KIB	actual stock of inventories
KIBD	desired stock of inventories
LI	labour income
LPROD	labour productivity
m	markup (ratio of price to cost)
MH	man-hours
MS	money supply
N	employment
P	price level
Pa	absorption price
Pc	consumption deflator
PCPI	consumer price index
PD	price of domestically produced goods
Peq	steady-state "equilibrium" price
PEN	price of energy
PF	foreign prices (in foreign currency units)
PFD	final demand deflator
PFX	price of foreign currency (Cdn. \$/U.S.\$)
PGNE	gross national expenditure deflator
PGP	"generated" price
PGPP	price of private business product
PK	rental cost of capital
PM	import price
POTH	"other" prices
PQ	output price
PT	price of traded goods (both exported and imported)
PUS	U.S. price
PW	world price
PX	export price
r	interest rate
RDP	real domestic product
REL	steady-state ratio of the output price to the consumption price
RK	returns to capital
RNU	"natural" unemployment rate
RU	unemployment rate
S	proportion of final demand composed of imports
SALES	measure of final sales
TAR	tariff rate
TFP	trend factor productivity
TREND	trend inventory-to-sales ratio
TX	indirect sales tax
UGNE	real gross national expenditure
UKC	unit capital stocks
ÜLC	unit labour costs
UPm	unit import prices
UTX	unit taxes
UVC	unit variable costs

## APPENDIX

### Variable Mnemonics and Description

#### Variables:

V	real wealth
W	wage rate
Weq	steady-state "equilibrium" wage rate
WTR	trend growth rate of wages
YC	corporate profits before tax
YDP	disposable personal income

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